Nuclear Track Filters as holders of magnetic fluid: A composite polymer-ferrofluid system

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The basic technique for production and a new application of nuclear track filters as holders of ferrofluid or magnetic fluid is reported. A simple technique is described for filling the pores of makrofol (polycarbonate) Nuclear Track Filters (NTFs) with magnetic fluid under the influence of an external magnetic field. The processed Makrofol NTFs may be used in a number of technical applications, besides their possible use as composite polymer-ferrofluid systems and conducting polymers.

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1. Introduction

With the advent of magnetic fluid – a liquid carrier having suspension of solid magnetic particles of sub-domain size (10 to 15 nm) with density of the order of 10^{23} cm^{-3}, and magnetic susceptibility 10^{-7} Hm^{-1}, a chain of exciting applications came up. These include magnetic fluid seals; bearings; magneto thermodynamic power generation systems; efficient audio speakers; dampers; rotary seals for computer disc drives; high speed non impact magnetic ink jet printing technique, besides many clinico-medical applications e.g. magnetic fluids as radio diagnostic tools etc. [1]. The suspended particles within the fluid sense the force due to an externally applied magnetic field and hence move the liquid bodily by imparting drag to it. In the present work, this fact was used to fill up the micropores of nuclear track filters (NTFs) for further use as devices. In general, a liquid can be forced into micron-sized holes in an NTF by applying necessary hydrostatic pressure depending upon the surface energy and the pore radius. The drag produced by an external magnetic field in a magnetic fluid, can, therefore, replace this hydrostatic pressure for filling magnetic fluid.

The great fascination of NTFs comes in large measure from the wide-ranging diversity of technological and scientific fields in which the particle radiation damage track-etch technique can be applied. Technological applications of track etching have been described by Spohr [2] and include membranes for separation processes and medical applications; magneto-optic materials; surface texturing; super insulators; field ion emitters; micro-composite materials; super fluidity; new electronic devices besides micro/nanostructures fabrication etc [2-7].

2. Experimental

The production of NTFs came as spin off from the interaction of heavy energetic ions, which create latent damage zones (called nuclear tracks) along the path of moving ions in a given dielectric. They are retained and stored infinitely in many such materials as plastics, glasses, micas, and rocks. The damage sites can be used to initiate a phase separation process by a suitable method that removes or transforms the host material along the nuclear track.

The most common method is track etching, which makes use of chemical etchants. The latent nuclear tracks are chemically ‘amplified’ preferentially so as to produce statistically distributed pores of well-defined dimensions and porosity. The whole technique has been explained in detail by many workers [2-7]. Fig. 1 shows stochastic distribution of etched ion tracks of 238U ions (13.6 MeV/n, 106 cm^{-2}) in 60 µm thick makrofol polycarbonate (Bayer AG) irradiated at UNILAC, GSI, Darmstadt, Germany. The etched pore diameter is 2 µm and the pores are seen through and the etchant used was 6N NaOH, 70 °C.

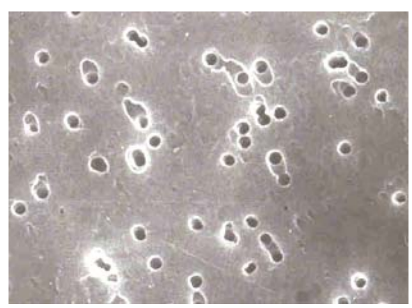

Fig. 1. SEM micrograph of etched pores in Polycarbonate NTF.

As stated earlier, for forcing a liquid into such a system having micro dimensional pores, a necessary hydrostatic pressure is required. This is equal to 2ES/r where ES is the surface energy (102 to 103 erg cm^{-2}) and r is the pore radius. The optimum hydrostatic pressure was applied using an external magnetic field over the makrofol NTF. The simple experimental technique is shown in Fig. 2. When a droplet of magnetic fluid was placed over the upper surface of NTF, it was pulled along the pores besides a quick spread over the surface.

The NTF with its pores plugged with magnetic fluid was lifted carefully and dried in the oven (50 °C, 2 hours). The extra fluid was wiped away using dry cotton. In order to check that the fluid contents that have been stored in the pores, a direct method was used. When a permanent magnet was brought closer to the NTF, the composite heterogeneous polymer ferro-fluid system membrane was found attracted, indicating the filling of the pores with ferro-fluid.

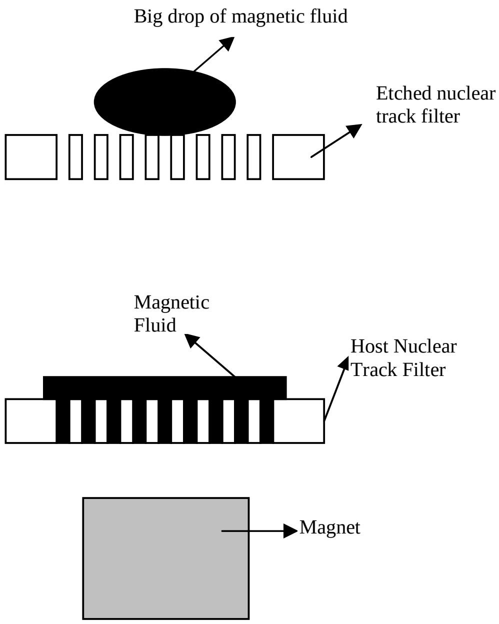

Fig. 2. Technique of filling magnetic fluid in the pores of an NTF.

3. Results and discussion

There can be some more technical applications of the resulting system. Since there can be large number of such pores filled with magnetic fluid, it is suggested that each pore can be used as a discrete memory or storage cell. It can find its application as high-density storage media to be used in computer applications.

For the characterization of the microstructures by means of SEM, magnetic microstructures, freestanding on the copper tape [having conductive adhesive], were observed by dissolving the polycarbonate matrix in dichloromethane. The cleaned and dried samples were mounted on the specially designed aluminum stubs with the help of double adhesive tape, coated with a layer of gold palladium alloy in “Jeol, fine sputter JFC 1100” sputter, coated and viewed under “Jeol, JSM 6100 scanning microscope” at an accelerating voltage of 20 kV. Images were recorded on the photographic film in the form of negatives at different magnifications. The magnetic microstructures having diameter of the order of 2 μm with stochastically distributed elements revealing the finer details of the constituents and of the etched pores of the host NTF are shown in Fig. 3.

It may be of interest to note that one can generate microstructures containing well-aligned magnetic dipoles each of length equal to thickness of the NTF used whose pores would serve as templates for growth. This can be achieved by dissolving the NTF in a suitable reagent, which would not react with the dried magnetic fluid settled into the pores. Such metallic arrays have already been produced using this method [5]. The principal behavior of thin ferromagnetic films used as storage medium has been discussed elsewhere in detail [2]. With the application of an external magnetic field, discrete magnetic domains – so called magnetic bubbles, are formed in the ferromagnetic films. The storage capacity depends upon magnetic domains per unit area. The similar studies may also be undertaken as a system containing micro magnetic dipoles. The other possible applications of the magnetic and dielectric properties may include the investigations of the magnetic and dielectric properties of such composites as heterostructures.

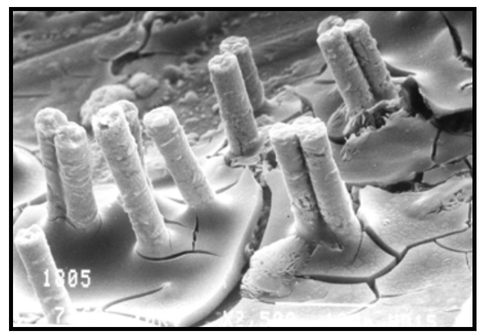

Fig. 3. SEM micrograph of solid microstructures of magnetic fluid.

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